Interactive End-User Creation Of Workbench Hierarchies
Within A Window System

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Abstract — Conventional command-language interfaces to
interactive computer systems do not support the problem-solving
behaviour of users in a natural way. They supply a single view
into a sequential stream of actions, whereas people normally juggle
many activities concurrently, switching rapidly from one to
another. They provide a wide and flat command structure which
is fixed and insensitive to the context of the dialogue. They offer
little opportunity for personalization, while people differ radically
in what they do and how they prefer to do it.

This paper describes an experimental interface which
supports parallel activity through user-defined extensions to a
basic command interface. Windows provide multiple independent
views into the system. Workbenches supplant the flat command
structure. A specialized direct-manipulation editor allows easy
creation and maintenance of workbenches by novice and expert
alike. Users are encouraged to create their own informational
support environments and to alter them as their activity dictates.
The scheme complements the normal command interface and
utilities can be invoked in whichever way seems most natural.

Introduction

Conventional command languages are widely used to
communicate intentions to the interactive top level of a computer
operating system. A powerful working environment can be
constructed by combining linguistic expression — which provides a
terse but simple dialogue — with the flexibility of allowing
experienced users to combine commands and create their own.
But one of the biggest drawbacks to such interfaces is their
sequential nature. They are unsuited to parallel activity such as
consulting an on-line manual, looking up references when
preparing documents, checking calendars when composing mail, or
responding to urgent higher-priority tasks. Sequential dialogue is
a poor match to the highly parallel thought processes of people.

In contrast, modern interfaces are window-based and thereby
permit parallel activity. Transient pop-up (or pull-down) menus
focus the dialogue to the window's current context. Supporting
metaphors supply the user with a model for making sense of the
interface complexity. For example, the screen is a desktop in the
Xerox Star (Smith et al., 1982) and Apple Macintosh (Williams,
1984). Applications take advantage of windows to give multiple
views into information structures like documents. Similarly,
interactive programming environments use an integrated toolbox
paradigm for program development, where tools are highly tuned
to the application. Smalltalk-80 (Goldberg, 1984) and Interlisp
(Telkesman, 1979) are two good examples within the genre. But
the structure of each context-dependent view within a window is
normally imposed by the system designer. Changing this view is
difficult or impossible for the end user, forcing him to conform to
a standard which may not fit his current needs.

The present work explores the possibility of supporting
parallel activity through user-defined extensions to a basic
command interface. A main command window (or several of
them) supplies the primary channel of communication with the
computer operating system. Independent workbenches can be
created — grouped hierarchically if necessary — to support
parallel activity. These contain context-dependent pop-up menus
to initiate supporting commands. Each workbench is associated
with a window which displays any resulting output.

What is novel about this scheme is that context and
workbench creation is totally user-defined. A specialized direct-
manipulation editor allows easy creation and maintenance of the
workbench infrastructure and the pop-up menu contents by novice
and experienced users alike. The intent is to encourage users to
create their own informational support environments and to alter
them as their activity dictates. while retaining the convenience of
separate windows with associated pop-up menus.

In order to set the scene before plunging into details of the
workbench creation system, the paper begins by discussing aspects of
parallelism in user activities, workbench paradigms, and
personalization as a path to system flexibility. The subsequent
section describes how workbenches can support a command
interface. Illustrations and examples demonstrate the workbench
in action. The thrust of the paper follows — personalization
through end-user creation and editing of the workbench
infrastructure. Finally, implementation issues and future
directions are discussed.

Parallelism, workbenches and personalization

This section introduces three concepts fundamental to our
work: supporting user activity through parallelism; organizing
activities with workbenches; and matching user requirements with
system offerings via personalization.
Parallelism

Traditional interactive interfaces are highly sequential. Most conventional command languages insist on completing the current activity before the next one can begin. Hierarchical menu structures compound this constraint — before a command can be invoked, the user must navigate from the current location in the hierarchy (the previous activity) to the desired target (the next activity).

Despite the sequential nature of traditional command interfaces, much parallelism arises naturally in interactive dialogues with computers. Documentation must be consulted, references checked, subsidiary programs run, and so on. Parallelism also occurs when the current activity is unexpectedly pre-empted by more urgent tasks, only to be resumed later. A user will generally internalize complex sequences of parallel activity while running tasks sequentially on the computer.

The model of computer-supported parallel activity provides a realistic framework for aiding the user's cognitive thought processes — specifically his short-term and working memory. As Shneiderman (1984) summarizes:

Short-term memory is used in conjunction with working memory for processing information and problem solving. ... If many facts and decisions are necessary to solve a problem, then short-term and working memory may become overloaded. ... [In addition, these memories] are highly volatile; disruptions cause loss of memory, and delays can require that the memory be refreshed.

Shneiderman, 1984

In practice, sequential dialogues provide little support for storing intermediate results of an action. For example, a programmer requiring documentation on a language construct must leave the editor, invoke the programmer's manual, find and read the required information, and finally recall the editor. The cognitive cost of using this information is high. He must recall his mental location within the program, remember the retrieved information, and apply it. Obviously, a high load is placed on short-term and working memory, resulting in inefficiency due to memory failure.

What is required is interactive support of parallel activity. Certain command languages (such as the Unix C shell; Joy, 1980) support primitive parallelism: tasks (called processes) can be suspended and resumed on demand. This practice provides only limited benefits, for only one viewport into these processes is allowed. Window-based interfaces address the viewport problem very nicely. They are specifically designed to permit parallel activity by providing a variable number of virtual views into a given structure, all mapped to a single physical screen. But windows also system complexity, for the user must now physically manipulate the windows and keep track of which one does what.

Constrained systems — such as workbenches — help to minimize confusion by limiting actions in a window to the context of the subsystem running in it.

Workbenches

A second concept fundamental to this paper is that of the workbench, a metaphor for categorizing and accessing system utilities. We introduce this topic first by describing the difference between unconstrained and constrained dialogues and then by looking at organizational methods within the latter.

There are several different approaches available for interfacing with interactive systems, such as conventional command-driven interfaces, menus, forms, natural languages and icon-based metaphors (Witten & Greenberg, in press). Although quite different at the presentation level, they can usefully be compared according to the extent to which they constrain the user's actions. An unconstrained system (such as a command interface) allows the user access to all facilities at any time, while a constrained system (such as a menu hierarchy) limits actions to the context of the current subsystem.

General-purpose computers almost invariably each a context-dependent dependency between sub-systems by making all tools available at any time in the interaction. Because of the virtually infinite range of activities which may be required in unconstrained dialogues, linguistic expression in a command language is the conventional medium for the expert user to convey his intentions to a general-purpose system. Unfortunately, this power is also the system's failing — the user may not desire such a high degree of freedom within what he considers familiar contexts (Thimbleby, 1980).

In order to reduce the cognitive load imposed by a rich set of commands, the utilities which can be invoked by the user are sometimes arranged hierarchically to assist him with his work. Utilities are divided typically into minimally interacting subsystems. This kind of organization (although dealing with passive information rather than active utility programs) is exemplified by Videotex, a generic name for systems used by the general public for information retrieval, tele-shopping and tele-banking. Activities are normally accessed via a menu selection dialogue where each menu category represents progressive refinements of "fields of knowledge" (Tompa, 1982). Another good illustration is the Apple Macintosh (Williams, 1984), in which applications normally interact through an intermediary. For example, including a figure in a text document involves creating the figure in the "Macpaint" application, posting it in an intermediary scrapbook, leaving Macpaint and invoking the "Macwrite" application, and finally retrieving the figure from the scrapbook. Although division of the system into utilities is useful for routine tasks, it is necessary to leave the current context and enter a new subsystem in order to perform unusual actions. The result is a dialogue which is tedious to use unless it happens to be well-tailored to the user's needs while working within a given subsystem. A better paradigm for highly interacting sub-systems is found in the workbench/toolbox metaphor.

Nakastani and Rohrich (1983) propose a method of integrating links between subsystems by analogy with tools in a workshop. The hierarchy used is a tool box, which is the entire set of tools, a workshop, which collects similar tools, and a workbench on which the actual work is done. Toolboxes and workbenches differ from conventional hierarchies in that actions (verbs) are categorized instead of objects (nouns). Workbenches contain tools appropriate for acting on the object(s). Example objects may be the complete system environment, a collection of files, or a single file. Example workbenches are a viewing workbench for editing, displaying and listing files, a language workbench for compiling and debugging programs, and a manual workbench for accessing the programmer's manual.

A recent project at Bell Laboratories, called Menuix, shows how an extensive and flexible operating system interface can be implemented with menus (Perlman, 1984). One consequence of menu access to Unix programs is that the vast selection of utilities must be structured somehow into reasonably small subsets; otherwise the menu would become unmanageable. System
programs are assigned to workbenches — arranged hierarchically — and a program menu displays brief (half-line) descriptions of the programs in the current workbench. When a program menu entry is selected, arguments are requested and the program is executed. In order to implement the hierarchy, an entry in a workbench may point to another workbench (in the same way that an entry in a directory may point to another directory in the file hierarchy). Selecting one of these entries will replace the current program menu accordingly. Menunix provides integration by using the workbench metaphor to unify the user's view of the system.

Menunix does not seem to have gained wide acceptance, perhaps because it uses sequential access to drive a paradigm which is best viewed in parallel. But most modern interfaces use windows to provide parallel views, and transient pop-up menus to access generic functions. In sharp contrast to linguistic commands, fixed menus constrain the user to a small set of operations in each context. By mapping workbenches to windows (the working area) and tools to the transient menus tied to the window, a parallel workbench system is created.

Another problem of the workbench paradigm is matching the collection of tools with the user's requirements. We explore this in the next section.

Personalization

The ability to create virtual views into a workbench structure through the use of windows addresses parallel activity very nicely. So does the use of pop-up menus which remind the user what can be done in the current context and which offer a simple way of invoking relevant procedures. The more clearly the user's activity can be delineated, the more probable it is that a pre-defined scheme will be able to support it unobtrusively. In the case of everyday interaction with a general-purpose computer system, activity is unpredictable and varies enormously from one user to another. In this case a fixed scheme is unlikely to provide a good match to the user's requirements.

The arrangement and selection of workbenches is normally imposed by the system designer, and so users are forced to adopt a standardised view of the system (or suffer). For example, a typical mail workbench may contain tools to send, receive, filter, and edit mail. This is insufficient for the user who receives encrypted mail and requires access to a decryption tool. High overhead is involved if this tool belongs to a different workbench. In contrast, while some specialist systems (such as the Lisp machines and Xerox Dolphin) supply pop-up menus for context-dependent commands, they do permit the user to create his own windows and choose which operations to associate with their pop-up menus. However, only the highly skilled are likely to attempt this, and then infrequently and not as part of daily activity in coping with non-routine demands.

While the range of tools available may be very large, each individual user generally employs only a small subset of them (Hanson et al, 1984; Greenberg, 1984). Techniques of modeling the user promise to reduce his cognitive load by personalizing the environment to make available (or at least give preference to) only those commands which he is likely to invoke, and structuring them in a way which corresponds to the way he perceives the system. At its most basic, user modeling takes the form of a system designer interacting with the target population to adjust the system to fit the typical user's current needs (Eason & Damodaran, 1979). Unfortunately, users cannot accurately be viewed as "typical" in the normal case of a highly heterogeneous community (Rich, 1983). Edmonds (1982) suggests that our knowledge of human behavior is inadequate to portray correctly the typical user — especially one whose need will change over time. An alternative personalized outlook shifts the design focus towards a collection of models of individual users.

Explicit personalization, where the user explicitly alters his working environment to suit himself, offers the greatest potential for personalization — at least in the short to medium term (Greenberg, 1984). The ability to tailor one's working environment seems to be an important attribute of what are termed "user-friendly" systems. Examples are the use of a profile statement which is interpreted automatically on login, control over system parameters (such as the prompts), making appropriate entries in abbreviation files, and placing utility programs so that they will automatically supersede the standard system utilities when invoked (as supplied in the Unix C-shell; see Joy, 1982). Unfortunately the possibility of explicit personalization raises its own problems. In order for the user to construct the model, he usually needs fairly advanced knowledge of the system and its capabilities, possibly negating any benefits. Although inferential automatic modeling may offer a solution to this, it is very difficult to do for the general systems we are taking about.

With general-purpose workbenches, there is an excellent case for extensive explicit personalization so that the user can set up his own options in pop-up menus and specify their effect in terms of invoking system commands, creating new windows, and so on. In order to reduce set-up overhead, and to encourage frequent re-modeling by novice and expert alike to reflect changing task requirements, it is essential that easy-to-use tools be provided for constructing and maintaining the models.

Workbenches in a conventional command-driven interface

The rest of this paper describes the workbench creation system (WCS), which supports command-driven interactions with the Unix operating system through a window interface, the Jade window manager (Unger et al, 1984). Print on paper is a poor medium for explaining highly interactive systems like WCS: we use simulated snapshots of the workstation screen to help convey the nature of the interface.

The user pursues his primary activity through a command window (several parallel command windows may be created if desired). He is supported by an infrastructure of specialised windows (workbenches) which can be used to provide relevant information (Figure 1). This is much more than a set of views into a passive text database, for arbitrary Unix commands, shell scripts or local programs can be associated with pop-up menu items. In fact, the user can define his own hierarchy of workbenches in the specialised windows, thereby creating an individualised classification of Unix commands and non-standard utility programs.

Each workbench comprises a window and associated pop-up menu. Entries on the pop-up menu may be of three types. The first invokes a Unix command which produces output only. Arguments may either be specified when the menu item is created or requested when it is picked. For example, a "Manual" workbench may provide two commands, entitled "Title" and "keyword" (Figure 1). Both have one argument, which is solicited in the workbench window by the prompt "Title of manual entry:" for the first command and "Keyword contained in manual entry:" for the second. The first invokes the Unix man <argument> command, and the second invokes man -k <argument> (which is Unix man's way of specifying a keyword search). In either case the output of the man command appears in the workbench window. One enhancement of this arrangement is the automatic
insertion of the output into a simple cut and paste editor, allowing scrolling, altering, and saving of results. Additionally, as the window may be of arbitrary size, the workbench and its contents may be shrunk and recalled later.

The second type of pop-up menu item invokes an interactive Unix command. If no process is running in the workbench, the sub-system invoked through the menu will run in its window. Otherwise, the workbench is duplicated in a new window and the command executed there.

The final type of pop-up menu item enters another workbench. This creates a new window on the screen and associates the appropriate pop-up menu with it. The old workbench window remains on the screen and can still be accessed, along with its pop-up menu. As a consequence, the user may have entry points into many different parts of the workbench hierarchy.

The WCS operates in the environment of the command window that spawned it, allowing each workbench to share global notions such as the current working directory. For example, a workbench that lists files will list those of the current directory even after it has been changed in the command window.

The example in the Figure represents a scenario where the user has created workbenches to help him compose a command in the "command" window for putting text files through nroff, a text formatter. Of the two "manual" workbenches, the first invoked a keyword search for the title of a manual entry. The second was used to display the entry. A "list" workbench listed the files in the current directory, and a "bibliography" bench allowed perusal of references (perhaps used in the text files). In this illustration, the "benches" window is the root of the workbench hierarchy.

End-user creation of workbench hierarchies

Central to the WCS is the method of creating and altering the support system of workbenches. Without the ability to personalize it the interface would have limited novelty, being simply a way of allowing users to navigate through a predetermed hierarchy of utilities. Although superior to non-windowing workbench interfaces such as Menunix (Perman, 1984) — in that, once accessed, a workbench remains immediately accessible as a window on the screen until it is explicitly deleted by the user — the workbench paradigm contains no fundamentally new ideas.

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**Figure 1: Workbenches as a support structure**
But the inclusion of an end-user creation/maintenance system provides an interesting medium in which to explore explicit user personalization in a rather sophisticated interface. It is essential to success that modification be quick and easy, for if not, novice users will be denied access to a tool which should make work much easier for them, and expert users will not alter the support structure to reflect changing requirements. These drawbacks are evident in most existing explicit user personalization systems. A direct-manipulation interface reduces the usually complex task of setting up windows and pop-up menu contents into a matter of form-filling (Figure 2).

The user defines workbenches in the first place by filling out and editing a simple form. This specifies the name of the workbench and the name and action associated with each pop-up menu item. Actions are of three types: the first executes a Unix utility or user-defined program which produces output only, the second executes interactive utilities, and the last enters a new workbench. In the first and second case, the Unix command is specified along with the name of the menu item. It may contain arguments (given in the usual Unix shell notation), in which case a prompt must be entered to solicit each one when the menu item is picked. In the last case, when the menu item specifies another workbench, that workbench must also be defined in the same way.

Along with each menu item is associated a HELP window which the user can see at any time by pressing a "HELP" button on the mouse. By default, the WCS displays the Unix command associated with the selection. However, the user is invited to specify the contents of each help window when creating the workbench. This encourages workbenches to be documented when they are created, removing one of the most severe drawbacks to

\*A good overview of direct manipulation is found in Shneiderman, 1983

Figure 2: The workbench editor
explicit personalisation — that a user becomes confused and disoriented when faced with another's model (for example, when helping him on a terminal). Although we do not check that the user-supplied HELP information is accurate, the fact that it must be provided before a workbench can be completed should encourage sensible use.

Direct manipulation is used as far as possible in the WCS. A user edits or expands an existing workbench by traversing the workbench hierarchy in the normal way and then selecting edit from the pop-up menu. The window becomes a workbench editor, with a concrete view of its pop-up menu appearing inside (Figure 2). Attributes of each menu item are listed in fields next to the item. These attributes and all other workbench entries may be altered at will. At any point, the user may choose to accept, reject, or pause the editing session.

The direct manipulation paradigm is also used to edit the hierarchy (Figure 2). New workbenches are added by creating a new menu item in the parent, selecting that entry, and editing the empty workbench. Removing an entry point deletes the workbench. Attributes are duplicated between windows through cutting and pasting. For example, copying the name of a menu item from one workbench to another duplicates all attributes associated with that entry. If the item was an entry into a child workbench, the complete hierarchy is duplicated.

Figure 2 shows a user modifying a workbench infrastructure. He is editing two benches, "Manual" and "Bibliography". Within the editing view, selection boxes indicate the menu entry's type (B for benches, I for interactive and O for output). For example, the "Edit bib" entry is a program which would be run interactively in the Bibliography workbench. Attribute fields are displayed only if appropriate, i.e. the "Prompt" field is visible only if a variable argument was specified in the "Command" area. In the Figure, the user has copied the "Browser" item from the Bibliography menu to the Manual menu. As this item is actually an entry to a workbench sub-tree, the complete sub-tree is duplicated.

The workbench creation system sketched above is an effective user interface prototyping scheme for windowed interfaces with pop-up menus. With it, one can easily and interactively build a window interface for a command-based interactive program. For example, a Unix software tool with a plethora of switches to generate different variants of its behavior can in a matter of minutes be given a smooth, window-based, interface which is controlled by pop-up menus, each having pertinent context-dependent help.

Implementing the WCS

The workbench conceptual model

From the user's perspective, the WCS has two conceptually different components. The first is the workbench access system, which allows users to interact with a pre-defined workbench model. The second component is the workbench editor, which alters the model (Figure 3). The rest of this discussion will be concerned with the implementation details of those components which are kept hidden from the user.

The workbench model is defined by a recursive intermediate script language. In BNF form, this language is defined in Figure 4a. In the Figure, ItemName, Help, UnitCommand and Prompt are character strings. Of special interest is the recursive appearance of WindowType within the BenchItem definition, for it permits the user to construct a tree structure of workbenches. Figure 4b illustrates one realization of the script language using a

![Figure 3: The conceptual model of the WCS](image)

Lisp-like syntax. Except for the help window contents, which are abbreviated to <help> for brevity, the example completely defines the workbench hierarchy of Figure 4c.

Each workbench carries with it its location in the model. For example, the "Manual" workbench of Figure 4c points to its corresponding definition in Figure 4d. Sub-trees may be included in this description as they are nested in the workbench definition. Editing a workbench is simply a matter of altering a localized view of the model.

The workbench implementation model

The workbench creation system is conceptually simple in design, consisting of five fundamental processes: a unique environment process, workbench controllers for each bench, program servers to execute programs in a window, cut and paste editors for filtering program output, and workbench editors for editing the workbenches.

Consider the model in Figure 5. After invocation from the user's command window, two processes are spawned. The first is the environment process, which maintains a common working environment between all benches and the original command window, and which creates program servers upon request. The second process is a workbench controller, which is responsible for activating the four types of user requests.

The first asks the workbench to create a new child bench. The controller for Workbench 1 in the Figure is shown spawning a child subtree. A new controller is recursively created, and is given a pointer into the workbench model which describes its activities.

Running Interactive programs involves requesting a program server from the environment process (Workbench 2 in the Figure). Cooperation between server and the workbench controller allows program execution in the appropriate window. Non-Interactive programs invoke similar actions, except output is filtered to a cut and paste editor spawned by the controller (Workbench 3).

The final task of the controller — workbench editing — invokes a special editor process whose effect is to alter the intermediate script language of the workbench (Workbench 4).

Figure 5 does not show all the details of process interactions. For example, the workbench editor does not edit the intermediate script language directly, for it must go through a master script editor which is responsible for maintaining a consistent workbench
Figure 4: The intermediate script language and an example

Figure 5: The implementation model of the WCS
model. Another hidden detail is that the environment process
knows the status of all workbenches. Upon request, it may record
the location and activities of all benches on the screen, allowing
the user to “save” his workshop between sessions.

Difficulties in implementation

Although the workbench model described above is simple in
design, implementation is difficult, partly as a result of the Unix
operating system. The first problem stems from the number of
processes created for a large number of active workbenches, for
Unix restricts the number of processes a user is allowed. Our
implementation multiplexes all workbench controllers into a single
process. Although messy in practice, it is totally transparent to
the user.

The second difficulty arises from the distributed nature of
our work. Our model allows processes to run on (or between)
workstations and a Unix host (a Vax 11/780). For example, the
cut and paste editor and the workbench editor reside on a
workstation. Program servers are actually two communicating
processes running on the host and the user’s workstation. The
execution location of an individual program is determined by the
program itself. Fortunately, the WCS is built upon the Jade
inter-process communication protocol, which elegantly handles the
distributed nature of our system (Unger et al, 1984).

But the major problem comes from the nature of the WCS,
which attempts to amalgamate two fundamentally different
paradigms — sequential command dialogues and cooperating
workbenches. In practice, many extra processes must be created
to support parallelism due to the sequential nature of Unix and its
underlying assumptions. For example, the environment process
of Figure 5 is necessary because maintaining a common working
directory between workbenches is difficult.

The marriage of the WCS to a modern interactive
programming environment would not only minimize these
problems but would also enhance its capabilities. The strong
notion of objects in Smalltalk (Goldberg, 1984) would allow
binding of workbenches to individual objects, such as documents,
files or graphical entities. The extensible nature of Lisp
environments (Teitelman, 1979) would eliminate naturally many of
the extra processes needed in our implementation.

The WCS has been partially implemented, and should be
completed by the summer of 1985. A prototype of the workbench
access system was recently released, and the workbench editor is
now under development. Currently, users may edit the
intermediate script language for personalization. That they are
willing to edit an internal language shows high promise for the
completed system.

Summary

The workbench creation system represents a synthesis of
many ideas. General purpose command languages, parallelism,
workbenches for constraining activities, and personalization are all
combined in a natural interface to offer the user flexibility in
performing tasks on a computer. We have shown how this
paradigm can be implemented on top of a conventional interface.

The thrust of our work is to provide a parallel workbench
structure which may be created and modified by the end user. It
is this aspect of personalization that the workbench creation
system exemplifies.

Most systems allowing personalisation do so at great cost to
the user in learning and modification time. Traditionally, the user
minimizes this cost by avoiding personalisation altogether or by
copying and modifying the profile of the local “expert”
(Greenberg, 1984). As the WCS is specifically designed to ease the
user’s burden, it should provide a good vehicle for studying how
users can effectively personalise their environment.

The union of explicit and automatic personalisation suggests
exciting new developments. We foresee an interface monitor
which keeps track of user activities and offers potentially useful
workbench configurations on request. When combined with a
knowledge base, the monitor may infer workbenches from minimal
user actions, possibly through stereotyping with existing models
(Rich, 1983). One consequence is rapid development of
workbenches suitable for transient user actions.

We envision a complete system which integrates all aspects
of modeling. Perhaps first time users will have a default
workbench structure to begin with (created by the designer
through discussion with users and through analysis of their needs).
It is a simple learning progression to go from modifying individual
workbenches, to adding new ones, and finally modifying or
creating new support infrastructures. The exciting possibility of
workbenches modifying themselves (possibly through consultation
with the user) would go even further to facilitate effective use of
the WCS.

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